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REVIEWS

The Copper Deposits of Ray and Miami, Arizona. By FREDERICK LESLIE RANSOME. U.S. Geological Survey, Professional Paper 115. Washington: Government Printing Office, 1919. Pp. 186, pl. 54, index.

The region described is about 70 miles southeast of the center of Arizona, in the mountainous district separating the plateaus of northeastern Arizona from the desert plains of the south. The Ray district lies in Pinal County; Miami is 18 miles north-northeast of Ray in Gila County, and 4 miles west of Globe, the geology of which was described by Ransome in *Professional Paper 12*.

A brief description of the earlier mining operations is followed by a bibliography and commentary. The stratigraphy of the region is then considered. The area is crossed by four ranges of hills and mountains, trending roughly northwest and southeast and separated by broad valleys which are partly structural in origin. The rock sequence comprises limestone and clastic sediments of pre-Cambrian, Cambrian, Devonian, and Carboniferous age, followed by intrusives of Mesozoic and Tertiary time, above which lie Tertiary and Quaternary clastics and lava flows. The succession does not differ markedly from that of the Globe district as presented in the work already referred to. The pre-Cambrian rocks are partly sedimentary, partly meta-igneous, as shown by chemical analysis and petrographic study. New formations are distinguished in the Cambrian, thanks to the better exposures in this area. These and the succeeding rocks are described in chronologic order, without separating the igneous rocks, as is the common custom.

Notable igneous intrusions occurred during Mesozoic times, the magmas ranging from basaltic to granitic. Andesitic extrusions of Cretaceous age are noted; no definite progressive differentiation is observed. The early Tertiary, too, was marked by acid and intermediate extrusions, and these were succeeded in turn by the deposition of conglomerates, sandstones, and flows of which the Gila conglomerate (provisionally assigned to the Pleistocene) is especially noteworthy; this formation is thought to be of alluvial origin and has a thickness of 2,500 feet; it offers attractive problems to the student of sedimentation.

A table shows the correlations of the rocks with the Grand Canyon section.

Structurally the region forms a part of the Great Basin Province. The faulting, which is especially prominent in the southerly ranges, is of the mosaic type, the displacement being normal for the most part, though thrusts are known, possibly attributable to the crowding incidental to block faulting. Excellent plates illustrate the topographic effects of homoclinal structure. Folding is, on the whole, negligible, though some of the field relations might be explained on this basis. The block faulting is supposed to be an expression of larger movements of the same sort, and the great valleys between the four ranges, the Globe Hills, the Pina-Mescal Mountains, the Dripping Springs Range, and the Tortillas, are all thought to have a tectonic rather than a purely erosive origin.

The ores of Ray and Miami are of the familiar disseminated type, the ore bodies being large and of tabular form. The metallization did not follow regular or systematic zones of fissuring, but networks of small fractures resulting from widespread disturbance of the rocks. The ore bodies are undulating, flat-lying masses of irregular horizontal outline and variable thickness, and they mostly lack sharp boundaries. The ore body constituting the east part of the Miami-Inspiration zone has a total length of 5,500 feet and a maximum width of 1,600 feet. The average thickness of the Ray ore body is estimated at 120 feet and its maximum at 400 feet. The average thickness of the Miami ore zone has not been estimated, but is somewhat greater.

The shapes of the ore bodies have been determined largely by extensive drilling, and graphs in which the copper assays of drill-hole samples from various depths are plotted, are used effectively to bring out the demarkation between the three principal zones, (1) the leached zone nearest the surface, (2) the zone of sulphide enrichment, and (3) the unenriched protore.

By far the greater part of the ore in both districts is mineralized Pinal schist; a relatively small amount is mineralized granite porphyry or quartz monzonite porphyry. Drilling at Ray has disclosed important bodies of undeveloped ore in diabase.

The principal metallic minerals of the protore are pyrite and chalcopyrite. The protore at Miami appears richer than that at Ray, the average of 126 assays under the main Miami ore body being 1.18 per cent. At Ray the copper tenor of the protore usually lies between 0.3 and 0.7 per cent.

The principal metallic mineral of the sulphide ore is chalcocite, and the average tenor of the ore thus far mined by the Ray Consolidated, 1.7 per cent copper. The average tenor of the ore sent to the Inspiration mill in 1916 was about 1.55 per cent copper.

The oxidized material is of two kinds. The first carries chrysocolla, azurite, and malachite, and is in part rich enough to ship to the smelter. Such material is relatively little iron-stained and is formed by the encroachment of oxidation in nearly pure chalcocite ore. The second type of oxidized material is leached of copper; it is *not* stained blue or green, but is mostly reddish from iron oxide. It is formed by the oxidation of material carrying considerable pyrite. No criteria were developed for recognizing capping over rich ore bodies beyond the observation that very red capping is likely to overlie protore or thin, highly pyritic ore. Assays of this sort of capping show from a trace to 0.2 per cent copper. The average thickness of the oxidized zone at Ray is 250 feet (range 45 to 600 feet).

The lower limit of oxidation and the position of the ground-water level at the time mining began were far from coincident, the divergence being particularly striking at Miami. Drill holes show that enriched ore lies partly above and partly below that water level. This suggests that enrichment was related, in important measure, to an earlier topography. This conclusion is supported by evidence which shows that much faulting has occurred subsequent to enrichment bringing oxidized and leached material in some places in lateral contact with rich ore on the same level. Rounded fragments of crushed chalcocite ore and fragments of oxidized material are found in the gouges of a number of these faults. The Pleistocene (?) Gila conglomerate appears to have been deposited subsequent to most of the enrichment, for the ores lie deepest in fault blocks capped by this conglomerate.

The deposition of the protores is attributed to thermal solutions coming from deep-lying portions of the granite-porphyry magmas, probably in early Tertiary times.

E. S. B. AND C. H. B.

Gypsum Deposits of the United States. By R. W. STONE. U.S. Geological Survey, Bull. No. 697, 1920.

This bulletin was prepared to take the place of Bulletin No. 223 published in 1904, on the same subject. Since that time (to 1918) the production of gypsum has increased more than 300 per cent. In 1918 the production was valued at $11,000,000.